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ARTIFICIAL SODIUM CLOUDS. MULTIPLE DIFFUSION OF RESONANCE LIGHT

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ARTIFICIAL CLOUDS OF SODIUM. MULTIPLE DIFFUSION OF RESONANCE LIGHT

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[Following is the translation of an article by J.E. Blamont in Comptes rendus des seances de l'Academie des Sciences (Reports Presented at the Sessions of the Academy of Sciences), Vol 250, Paris, 18 January 1960, pages 567-569.]

From the optical point of view, the principal characteristic of sodium clouds described in a previous atricle (see J. E. Blamont, Comptes rendus, Vol 249, 1959, page 1248) is that they are the site of an important multiple diffusion: the light emitted by the cloud is not constituted solely of resonance photons emitted by the sodium atoms after their excitation by the individual pencils of solar light, but , since the optical density kl of the cloud is high, a resonance photon is absorbed and reemitted several times by the atoms of the cloud before it reaches the observer. The properties of the light emitted (width of the ray, the ratio D_2/D_1, polarization) are modified in comparison with what they would be in the absence of multiple diffusion. If a theoretical model is used, the measurement of this modification permits the measurement kl, i.e. the concentration of sodium atoms at each point at each instant.

In our theoretical model which will be published in detail (C. Cohen-Tannoudji (in press)), the cloud resembles a long prism with square base, normally illuminated at one of its faces by a pencil of intensity I, the same for both lines D, and containing N_1 sodium atoms per cubic centimeter. The transfer of radiation in this volume is described by an equation in partial derivatives obtained as a generalization of Milne's theory. The solution, for conditions with limits appropriate to the problem, furnishes N_2, the number of excited sodium atoms per cubic centimeter at every point of the volume, in analytic form.

1. The ratio of intensity D_2/D_1. Figure 1 shows a curve, obtained in accordance with this model, which gives the variation of the ratio D_2/D_1, as a function of kl, in the light observed at an angle of 45° from the direction of excitation. It can be seen that it goes from 2 to 1 when kl varies from zero to infinity.

We measured this ratio in the two clouds with a Fabry-Perot interferometer (diameter, 7 cm; separation, 1 mm calculated for anti-coincidence of the two systems of rings D_1 and D_2, placed behind an afocal telescope with an enlarging power of 7). For example, seven measurements were obtained from the first cloud; the ratio moves from 1.10 (5 minutes after the start of ejection; altitude 115 km) to 1.40 (25 minutes after the start; altitude 105 km) showing, according to figure 1b, that kl varies from 30 to 3.

2. Width of the line. The method consists of measuring the absorption of light from the cloud by sodium vapor (see J. Bricard and A. Kastler, An. Geophys., Vol 1, 1944, page 53) by taking three photographs of the cloud through three containers with parallel faces, the first empty, the second and third filled with sodium vapor at 147 and 200° C (null, partial and total absorption). The absorption depends only on the width of the striking line and this permits the determination of the latter.

In principle, the width of an optical resonance line depends only on the Doppler effect. The measurements of diffusion previously presented (see J. E. Blamont, Comptes rendus, Vol 249, 1959, page 1248) show that thermal equilibrium is rapidly attained in the cloud and that the measurement of the width of the line from the cloud should permit the measurement of temperature at high altitudes.

In fact, the line is widened in the cloud by auto-absorption, due to the multiple diffusion, which is much more intense at the center of the Doppler line than at the sides. We have calculated an approximation for the widening (ratio of the visible width to the Doppler width) as a function of kl (fig. 1b).

$\frac{V'}{V}$: $\frac{\text{Resultant width}}{\text{Doppler width}}$

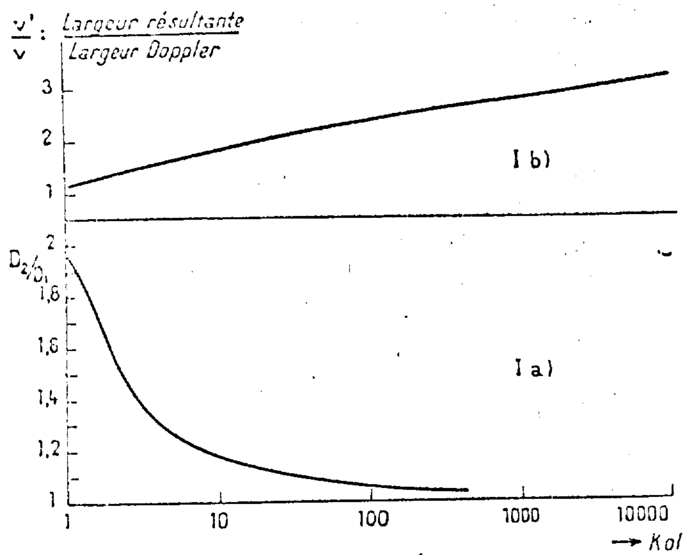

Fig. 1

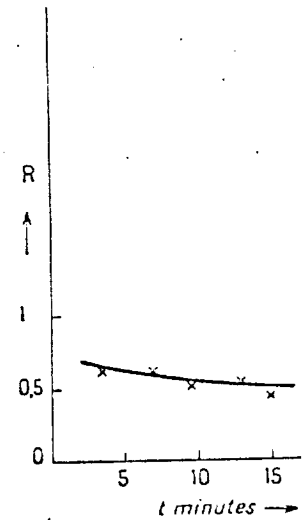

Fig. 3

Very many measurements of absorption have been obtained. The plates of figure 2 present two examples of absorption from an experiment of 10 March 1959: one example, two minutes after the start of ejection (weak absorption even in the hottest container, wide line); the second example at the end (total absorption in the hottest container, narrower line). Figure 3 represents the development of the factor of reduction by absorption as a function of time at an altitude z = 113 km. One sees that the width diminishes with time because of the disappearance of the sodium and tends to a limit corresponding to the Doppler width. The width does not reach this limit and it is therefore not possible to determine the temperature from it. Other analogous curves have been obtained for different altitudes. The imprecision of the measurements is due to the difficulty of making photometric measurements on film.

The width of the emission lines is exactly that which our model anticipated for the kl values derived from the measurements of the ratio D_2/D_1. Our measurements make multiple diffusion evident, prove the value of our theoretical model, permit the determination of the number of sodium atoms per cubic centimeter and show that the determination of temperature at high altitude is possible by the method of absorption provided that a quantity of sodium ten times smaller than in the course of our experiments (4 kg) is projected.

Sodium Cloud

Partially absorbed | Not absorbed | Totally absorbed

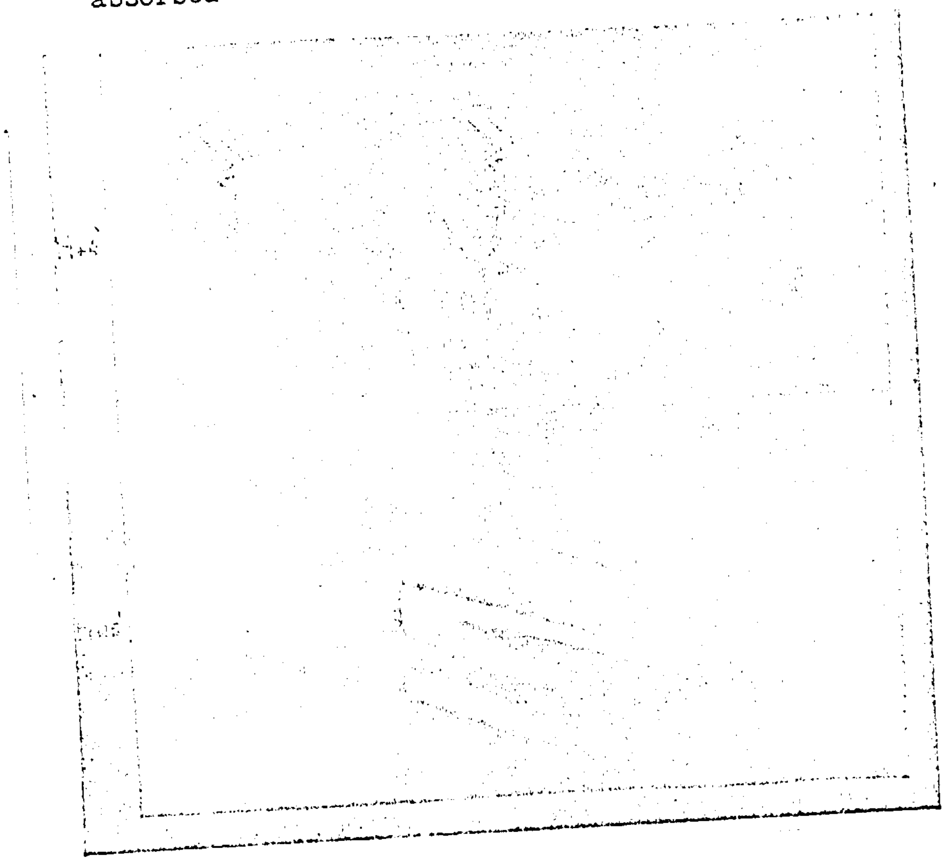

Fig. 2.

A detailed study of the results will be published in the future.

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